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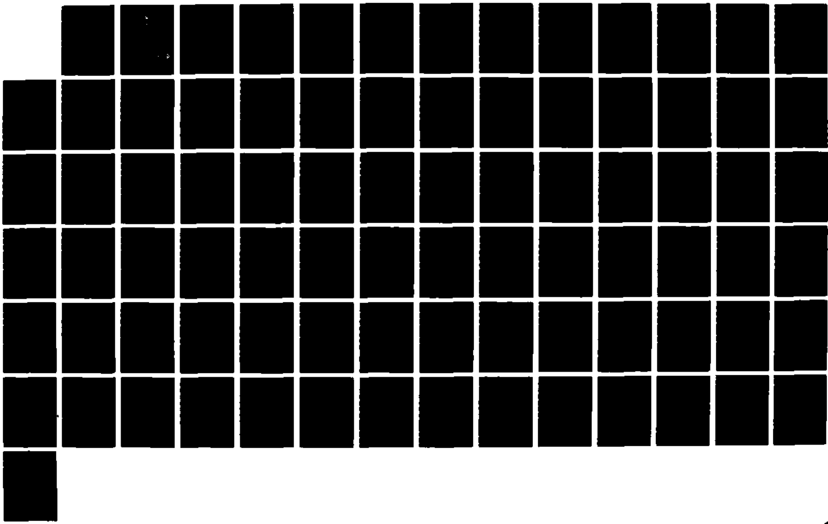

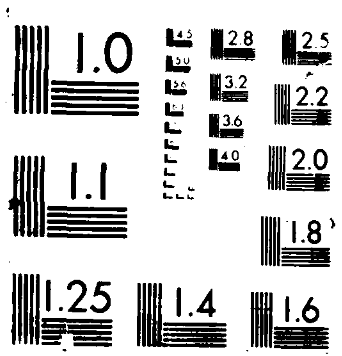
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# SUPPORTABILITY IN AIRCRAFT SYSTEMS THROUGH TECHNOLOGY AND ACQUISITION STRATEGY APPLICATIONS

THESIS

Debra L. Haley
GM-13

AFIT/GLM/LSM/87S-30

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# SUPPORTABILITY IN AIRCRAFT SYSTEMS THROUGH TECHNOLOGY AND ACQUISITION STRATEGY APPLICATIONS

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Systems Management


Debra L. Haley, B.S.

GM-13


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This thesis is dedicated to my son, Greg, who was born between Chapters 2 and 3.

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## Abstract

In September 1984, it became Air Force policy to consider supportability equal in importance to cost, schedule, and performance in weapon system acquisition. All levels of management, particularly system program office (SPO) management, must be made aware of wherein the weaknesses in Air Force design and contracting strategies, of how these weaknesses can be overcome, and of how these strategies can work together to place the needed emphasis on supportability. The objective of this research was twofold. First, it attempted to discover the importance of supportability in aircraft system design. Secondly, the research provided information for SPO managers to use in directing contractors, via contractual requirements, to design for supportability. It also provided program managers with information on technologies they can promote as supportable without sacrificing cost, schedule, and performance. To meet these objectives, 20 individuals managing advanced technology programs were interviewed. Interviewees also discussed how the system acquisition process could be improved to increase emphasis on supportability. Eleven advanced technologies are presented for their potential contribution to improving the supportability of future aircraft systems. Applications

of any of these advanced future aircraft systems. Application of any of these advanced technologies will result in at least one of the following: increased reliability, decreased need for support requirements (i.e., maintenance manpower, support equipment, etc.), or decreased maintenance repair time. Also, four acquisition strategies are presented for their potential contribution to increasing the level of emphasis placed on supportability in aircraft system design.

# SUPPORTABILITY IN AIRCRAFT SYSTEMS THROUGH TECHNOLOGY AND ACQUISITION STRATEGY APPLICATIONS

## I. Introduction

### Background

In September 1984, the Secretary of the Air Force. Verne Orr, and Air Force Chief of Staff, General Charles Gabriel, signed a letter stating the United States Air Force considers supportability equal in importance to cost, schedule, and performance in weapon system acquisition. These four factors are to be used to assess the value of contractors' proposals and to competitively rank each proposal submitted to the Air Force for a given acquisition.

For the purpose of this thesis, the following definitions apply. Cost is defined as the amount paid or payable for the acquisition of property or services (8:179). Schedule is that part of a contract which sets forth details of the property to be delivered or services to be performed in a given timeframe (8:610). Both these terms are used by system program office (SPO) management to assess whether the contract is within budget and will be completed on time. These are indicators of system progress used only during the acquisition phase. Performance and supportability are factors which will characterize the system throughout its life cycle. The performance factor controls the item being procured by establishing operating requirements supplemented by quality assurance provisions and form, fit, and function limits (8:518). Supportability is qualitatively and quantitatively defined by the activities that create and sustain warfighting capability. These activities include organizing, training, and equipping for the deployment and employment of aerospace systems. Supportability includes reliability and maintainability (R&M) characteristics of the system. All of these factors (cost, schedule, performance, and supportability) influence the decision process. During acquisition there may be tradeoffs between any two or more of these four factors as program requirements or priorities change.

The SPO is the only organization in the Air Force authorized to negotiate with contractors during acquisition. For this reason it is imperative for the SPO to be an advocate of supportability if its contractors are to design aircraft systems to be operationally supportable. The typical SPO is designed to find and develop a solution to a validated current or projected operational deficiency. The SPO explores concepts, studies and validates possible alternative solutions, and then manages the development and initial production of the new system. The SPO is the focus of all Air Force management and direction of weapon system acquisitions (17:4).

R&M 2000 is an action plan to institutionalize the Air Force commitment to accelerated reliability and maintainability improvements in new and fielded systems. Five goals in the R&M 2000 action plan focus Air Force efforts in the area of R&M:

1. Increase warfighting capability.
2. Increase survivability of the combat support structure.
3. Decrease mobility requirements per deploying unit.
4. Decrease manpower requirements per unit of output.
5. Decrease costs.

Note that improving R&M is not one of the goals; however, improving R&M is the vehicle for achieving the goals.

During the past three years, interest in supportability has filtered down to all levels of Air Force management and influenced the programs and activities they oversee. But, as a finding in the report of the President's 1985-86 Blue Ribbon Commission on Defense Management indicated, this influence is limited. This is due in part to the fact that logisticians, advocates of supportability in the SPOs, do not have the authority to ensure supportability is given the same consideration as cost, schedule, and performance factors in acquisition (40:8). A major task of the Blue Ribbon Commission was to evaluate the defense acquisition system, to determine how it might be improved, and to recommend changes.

In a 1986 article Dr. James P. Wade, Assistant Secretary of Defense for Acquisition and Logistics, also stated that senior logisticians in the SPOs do not have authority equal to that of the senior engineers and contracting officers. The lack of authority of logisticians stems from the need for: (1) a more integrated approach to logistics by the SPOs, and (2) quantified supportability tradeoffs (55:4).

Integrated approach refers to a team or system approach in designing aircraft systems. That is, all aspects of an aircraft system are considered in its development with emphasis placed on the optimum design of a system for its life cycle. The SPO is structurally organized to implement the integrated approach but that integrated approach is not used effectively in the day-to-day business of design. Marconi Von Spangenburg viewed the SPO's approach to design as segmented under separate management functions (54:64).

Acquisition logisticians must have quantitative data to define the tradeoffs between supportability issues and performance, cost, and schedule issues. One example of the gain to be made by quantifying supportability comes from Rockwell. "In the past, we would put our R&M guys in the same room with the engineers, and they would just start waving their arms around," noted the vice president for supportability, Advanced Tactical Fighter (ATF) systems, Rockwell International. Rockwell logisticians are beginning to replace "arm waving" with output from quantitative data bases containing supportability information. This has enabled them to interact equally with their engineering peers to influence design decisions (28:18).

It is the contractor who designs and builds supportability into aircraft systems. Therefore, SPO management must influence the contractor's supportability performance directly. The articles and report previously cited support the notion that mere guidance is not going to bring about the needed reforms to place supportability issues at the forefront in weapon system design. The Air Force must ensure industry's undivided attention is given to supportability through strong contractual incentives, both positive and negative. By raising the consideration level of supportability in source selection, increasing supportability incentives during development, insisting on warranties in production, and extending the contractor's participation and responsibility beyond the factory and into the field, the Air Force will be able to bring about the improvement desired (44:125).

As the Air Force continues to investigate ways to increase the level of supportability in current aircraft systems, it is recognizing that the intelligent application of technologies can result in significant improvements to supportability. For example, the High Reliability Fighter (HRF) Concept Investigation study effort identified opportunities in the technology base for reliability, maintainability, and supportability improvements. It then analyzed the impact of the improvements on aircraft design, and developed viable design concepts for the highly reliable fighter aircraft requiring minimal support (38). These technologies in the appropriate applications have the potential to increase reliability, decrease the need for support equipment, reduce maintenance manpower requirements, and/or decrease maintenance repair time.

All levels of management, particularly acquisition program management, must be made aware of wherein lie the weaknesses in Air Force design and contracting strategies, how these weaknesses can be overcome, and how these strategies can work together to place the needed emphasis on supportability. To focus more specifically on supportability, SPO management should:

1. Consider supportability equal to cost, schedule, and performance because of its contributions to life cycle cost and to operational availability of the aircraft system.

2. Use acquisition strategies to emphasize the importance of supportability.

3. Design new aircraft weapon systems from an integrated approach using state-of-the-art technology that from the outset emphasizes supportability.

## Statement of Problem

This thesis investigated how current and future technologies and new acquisition strategies can used to bring the supportability factor to a level equal to the cost, schedule, and performance factors in the decisions made by Air Force system program offices.

## Research Questions

The objective of this research was twofold. First, it attempted to discover the importance of supportability in aircraft system design. Secondly, the research provided information for program managers to use in directing contractors, via contractual requirements, to design for supportability. It also provided program managers with information on technologies they can promote as supportable without sacrificing cost, schedule, and performance.

## Research Questions

In the attempt to accomplish the research objectives, the following questions were investigated and answered:

1. What contracting strategies exist or should be implemented which would give equal consideration to supportability, cost, schedule, and performance in the acquisition process?

2. What current or new technologies will make future aircraft systems more supportable without sacrificing cost, schedule, and performance?

## Limitations of Study

This study was limited to investigating acquisition strategies and technologies which can be applied during the development and acquisition phases of Air Force aircraft systems. Technologies were limited to those applicable to major systems on aircraft researched by the Air Force Wright Aeronautical Laboratories.

## Literature Review

Importance of Supportability. The President's Blue Ribbon Panel on Defense Management stated:

> There is a need for an informed tradeoff between quantity and quality. At some point, more weapons of lower performance can overcome fewer weapons of higher performance [40:13].

With an increase in complexity comes a commitment increase in cost which, in the context of a fixed DOD budget, means fewer aircraft can be procured.

New technologies emphasizing supportability are beginning to be used in designs of new Air Force weapon systems. The result of these technologies will likely be higher aircraft availability. Highly complex aircraft which have supportability designed into give back through availability the quantity advantage which is lost with the high cost of complex aircraft. From this standpoint, supportability can be considered a force multiplier.

The concept of force multiplier refers to the qualities inherent in an aircraft system which provide the capability to quickly relaunch an aircraft on successive missions. The more aircraft which are launched, the higher the aircraft availability. This can be accomplished by assigning more aircraft per squadron, or keeping the same number of aircraft but making them more supportable (1:4; 17:7). Aircraft which are highly supportable can be relaunched with shorter turnaround times.

According to General Larry D. Welch, then Air Force Vice Chief of Staff, in 1985:

> The F-15 had no spare parts or manpower shortage but a reliability and maintainability (R&M) problem. The first F-15's had tremendous performance capabilities but frustrating R&M problems. What happened during the acquisition process was that in order to meet the threat, reliability and maintainability were traded off for performance priorities [18:10].

General Robert Russ, Commander of Tactical Air Command (TAC) in 1985, stated:

> Due to the "find and fix" approach used over the late decade on the F-15's, its reliability had been improved to the point that today it can fly two and a half times longer between corrective maintenance actions it could a decade ago. This is a force multiplier that translates into extra planes for a battle commander. A one percent increase in mission capable rate for a force of 700 F-15's is the equivalent of adding seven more F-15's to the inventory [18:10].

The "find and fix" approach to R&M has been successfully applied to other weapon systems resulting in improvements to the F-100 engine, avionics, modifications of the F-111, and offensive avionics update for the B-52 fleet.

In a 1982 Air Force Institute of Technology thesis, a research question was posed as to whether aircraft availability increased with improved aircraft maintainability. The research indicated there was a significant positive relationship between availability and percent reduction and percent reduction in repair time. Furthermore, the research found evidence indicating increased availability through reduced maintenance time was related to increased availability through additional aircraft (12:65-66).

Not only should supportability be viewed as a force multiplier from an availability standpoint, but also as a means to reduce operating and support costs and, in turn, life cycle costs. With the Air Force operating on a fixed budget, the less money spent on operation and support of aircraft systems, the more money that could be applied to other budget items. For example, the Air Force could place more emphasis on increasing the quantity of buys and the amount of research and development it funds. This reapplication of funds would have to be requested in the Air Force annual program and budget requests submitted to the Secretary of Defense.

In the final analysis, the ability of the Air Force to incorporate performance and supportability features in its aircraft systems will largely dictate the combat potential of prospective aircraft systems and their capability to successfully deter or engage an enemy (14:201-242).

Acquisition Strategies. The Pentagon in 1985 had contracts with 20,000 prime contractors and 150,000 subcontractors which together employed 1.25 million people throughout the United States. In 1985, the Pentagon paid to these contractors and subcontractors $246 billion for a wide variety of goods and services (19:144). With such a huge expenditure, and the need for a wide variety of goods, one would expect a lot of competition for government contracts throughout private industry. In actuality, the states of affairs in the DOD procurement structure may stifle competition and discourage firms from doing business with the U.S. Government.

A 1984 report to the President on the state of small business stated that within DOD (which accounts for approximately 80 percent of all federal purchase expenditures) the portion of prime contracts awarded to small business in FY82 was less than 20 percent. Further, DOD's buy was concentrated in the hands of a relatively few large business firms, with the top 25 receiving about 45 percent of the budget (52:23). Small firms contribute approximately 38 percent of the nation's gross national product (GNP) and represent over 98 percent of all U.S. business establishments. Small businesses are defined, in general, as those with less than 500 employees (13). The Small Business Administration (SBA) attributed this disparity to the multitude of regulations the Government has established in trying to assure the quality of what it procures. Compliance with these complex regulations is costly and discourage many small businesses from contracting with the Federal Government. As a result, DOD is not able to take advantage of the innovation of the younger, smaller entrepreneurial firms.

Currently only five percent of the Pentagon's total procurement dollars are awarded on a formal closed-bid basis. Sixty percent go out in contracts that are "competitively negotiated" with a few companies that the Pentagon officials deem "qualified." The remaining 35 percent of the DOD procurement dollars involve no bidding at all (19:144-145). They are used either to fund sole source programs between a single bidder and the Government or to extend existing contracts.

DOD, in establishing a new program, puts together a request for proposal (RFP). The RFP includes military specifications which, on larger programs, can run to thousands of pages. Industry then submits proposals in response to the RFP. The overly detailed RFP with its system specifications serves as a basis for defense contractors to prepare competitive proposals describing how they would meet the specifications. Preparation of competitive proposals may expose technical problems with the specifications or reveal modifications that would be most cost effective. The environment for program competition encourages improvements within the specifications but discourages modifications that deviate from specifications. This closes the door on one principal factor--tradeoffs between performance/supportability and cost--on which competition should be based. The resulting contract award, based mainly on cost, all too often foes to the contractor whose bid is the most optimistic (40:7).

Joseph Wright, Jr., Director, Office of Management and Budget, stated in 1985 that the procurement process needs to be simplified and competition increased. A goal, he said, is the shift from the use of complex design specifications to simplified performance specifications (39:C). DOD should reduce its use of military specifications when they are not needed and improve the usefulness of the specifications when they are needed. To do this could mean using a minimum of military specifications but supplemented with commercially used specifications. Military specifications could be based more on industry standards such as those published by the American National Standards Institute and the American Society for testing and Materials. This would provide the incentive for DOD to use commercial devices and products to a greater extent and attract more firms to bid on DOD contracts.

In support of these facts and opinions, the Report to the President on Defense Acquisition recommended that:

> Federal laws governing procurement should be ricocheted into a single, greatly simplified statute applicable government-wide [40:18].
>
> The Air Force RFP and Statement of Work should include a functional description of the desired product and not refer to military specifications. This would allow the bidders: 1) to choose from a wider range of technologies in responding to the proposal, 2) to use more commercially available products at more competitive prices, and 3) to respond knowing the proposal is evaluated for quality not lowest price [40:7].

Recognition of another deficiency in the military regulations has come to the forefront with the increased emphasis on supportability. This deficiency is in defining and calculating the parameters used as R&M requirements. Mean time between failure (MTBF), an example of a reliability parameter, is calculated from predicted or actual flight data. System R&M requirements are established by the using organization at the onset of the program. These requirements: (1) dictate the R&M design of the system, (2) serve as the basis for reliability demonstration testing, (3) are compared to flight test R&M measurements, and (4) are used as a baseline against which to both award reliability incentive warranties (RIW) and determine program success or failure. The parameters are not defined as part of the requirements but are left for interpretation by the organizations which generate, measure, report, or use them.

The user's R&M requirements are published in the Statement of Operational Concept (SOC) specifying, for example, a 150-hour MTBF requirement. What is meant by failure? Does it include all hardware failures or are there contractual exclusions? Are software errors included? MTBF is calculated as the number of failures divided by operating hours. What is meant by operating hours? Does it includes ground operation or just flight time? Should a factor be included to equate laboratory test time to flight time so the two sets of time can be added together to count as operating time? Nowhere in the DOD or Air Force regulations are these questions answered.

In maintainability, a requirement for mean time to repair time (MTTR) is exclusively a contract term as defined in AFR 800-18. Yet, it appears in the SOCs as an operational term as, for example, in the low altitude navigation targeting infrared for night (LANTERN) and anti-satellite (ASAT) programs. If the using organization has specified R&M requirements, then the parameters to measure these characteristics should be stated clearly to avoid any misunderstanding.

On actual example of this misunderstanding and lack of communication between user and developer is an existing avionics system. The avionics system requirement for

150-hour MTBF was satisfied as the developer interpreted the requirement. The contractor showed, via a reliability prediction, that the system design could achieve at least 150-hour MTBF. For a total of 1,740,000 system operating hours actual failures (hardware only) logged were 10,431. Thus, the MTBF of the system was 167 hours, surpassing the requirement. This data came from actual Air Force D056 field data (16:26). D056 is an operational data base for recording all maintenance actions performed on weapon system and associated equipment in the Air Force inventory.

The misunderstanding stems from the fact that of the 23,193 maintenance actions performed on this avionics system and recorded in D065, the developer found 2,188 to be "no defect" (no identifiable reason for outage): 2,966 were removals to facilitate other maintenance (not failure); 4,911 were actually caused by other on-aircraft maintenance actions; and the remaining 13,128 were labeled as failures. However, of the 13,128 failures, 900 were induced and, of the remainder, 1,797 were solved by adjustments. That leaves only 10,431 considered as relevant failures, resulting in the 167-hour MTBF reported by the developer. But the user had to deal with the real world number of 23,193 maintenance actions. As far as the user was concerned, all 23,193 maintenance actions were relevant and the system's real MTBF was 75 hours (18:26).

Spares and manpower were assigned to maintain this system based on the 167-hour MTBF. This discrepancy between the 167-hour MTBF and the user's 75-hour MTBF left the user with a system short of spares and manpower to perform the required maintenance.

The Air Force definitions of reliability and maintainability terms are not standardized across organizations. With this fact acknowledged, the Air Force has difficulty determining with any degree of confidence the gains and losses to be achieved through supportability measurements. Also, the Air Force cannot confidently award to its contractors reliability incentive warranties (RIW) for achieving supportability goals that are not previously defined.

Application of Technology. State-of-the-art technology is most often chosen for incorporation in a new or existing aircraft because it will increase some aspect of the aircraft weapon system's performance. Technology must be considered for what it has to offer from a supportability standpoint as well. New designs must use technology which enhances both supportability and performance. This was a conclusion reached by the President's Blue Ribbon Commission on Defense Management which stated:

> DOD should place a much greater emphasis on using technology to reduce cost--both directly by reducing unit acquisition cost and indirectly by improving the reliability, operability, and maintainability of military equipment [40:19].

The continued incorporation of advanced and highly complex technologies in aircraft systems has resulted in growth in the number of Air Force specialities (AFSs) required to keep the hardware operable. The complexity and diversity of the maintenance workforce specialty structure has made the maintenance organization very manpower intensive. In the past, this manpower intensive, highly specialized maintenance organization was tolerable because of the abundance of low cost manpower; operations from large, fixed industrialized main operating bases; and importance of massed force over force mobility.

Those things which permitted and encouraged a manpower intensive maintenance organization are changing. Manpower costs are increasing and so is competition among the Services for a dwindling manpower pool. The Air Force is also changing the way it plans to fight. No longer will it operate from large, vulnerable, fixed main operating bases. In the future, it will operate from a large number of dispersed locations in small self-sufficient units. This new strategy means maintenance units must be mobile and more flexible (3:3).

Effective operations under this new strategy can benefit from renewed emphasis on equipment designed to be supportable with two levels of maintenance, flightline and depot. This means improving component reliability and maintainability to reduce maintenance workload and increase weapon system availability. It also means maximizing "on-equipment" repair capability and reducing the need for deployed support equipment and "off-equipment" repair facilities.

The needed emphasis on supportability issues must be considered at the beginning of the design process and should continue throughout the life cycle of the aircraft system. This is crucial due to the way the Air Force approaches the design of new aircraft systems. Lt Col Don H. Story, Chief of U.S. and Allied Assessment on the Air Force's Checkmate Team, compared United States and Soviet applications of technology this way:

> When we determine the need for a new operational system, we tend to design from a blank piece of paper. The Soviet approach is more likely to take what has worked in the past and deliberately adapt or combine it with something else to meet their requirements. Because they avoid state-of-the-art technology, R&M are inherent in their systems. Because we design to state-of-the-art, we have to focus specifically on R&M [18:14].

Marconi Von Spangenburg noted another difficulty with the Air Force's current design approach. His view is that Air Force aircraft design suffers from the traditional approach of treating development of the hardware--the airframe, engine, and avionics--as separate issues under separate management. Only at the end of the development cycle is an attempt made to put them all together as a system. This approach negatively impacts both performance and supportability. Diagnostics, fault detection, and fault isolation are areas of supportability particularly impacted by this independent approach to design. It is the interaction between subsystems which can be a maintenance nightmare. When a problem occurs, it has to be determined from individual subsystem diagnostic codes wherein the fault resides. In many cases it is not an individual subsystem that is at fault but its interface with other subsystems and the airframe. In the design process, emphasis must be balanced from the outset between what is demanded of the aircraft system's operational capabilities and of the combat support system (54:64).

## Summary

A lack of supportability features in aircraft systems impacts maintenance personnel on the flightline; operations officers in the battlefield; supply personnel; budget personnel; and the list goes on. By using aircraft systems designed with state-of-the-art technology, the Air Force is taking the risk of developing complex aircraft without needed supportability features. It is imperative that system program managers recognize these risks and use available resources to overcome them.

There is great potential in terms of cost savings, increased service life, and quantitative advantages to be realized from aircraft systems if technology and contracting strategies are used to enhance the role of supportability.

## II. Methodology

### Research Plan

A literature review and unstructured interviews of Air Force personnel were the means by which information was acquired to answer the investigative questions. The unstructured interview was used to promote a free-flowing exchange of thoughts and ideas. Questions asked in each interview were tailored for the particular technology area being reviewed. Questionnaires did not allow for the variety of questions asked and would have required follow-up questions on an additional questionnaire. Follow-up questions could be asked during the initial interview. Also, questionnaires did not allow for elaboration of a subject area as well as an interview (2:211-12).

### Steps for Investigative Question One

Reports, theses, and journal articles written on Air Force acquisition practices were reviewed. This information was used to develop initial questions to be asked of personnel interviewed from: the Air Force Wright Aeronautical Laboratories (AFWAL); the Integrated Logistics Technologies Office (ILTO); and the Air Force Coordinating Office for Logistics Research (AFCOLR). From these sources, it was determined if existing acquisition strategies must be exercised more fully by system program managers to encourage emphasis on supportability in their aircraft system programs. If deficiencies in acquisition strategies existed, these were identified along with possible corrective actions.

## Steps for Investigative Question Two

A review of technical journals, magazine articles, and reports was conducted to provide the interviewer with a background of information on new technologies being developed for future use in Air Force aircraft systems. This background information was used to develop initial questions to be asked of personal interviewed from: the four Air Force Wright Aeronautical Labratories (AFWAL); the Integrated Logistics Technologies Office (ILTO); and the Air Force Coordinating Office for Logistics Research (AFCOLR).

## Interview Sample

To explain why personnel of particular organizations were interviewed, it is necessary to describe their organizations' missions and interrelationship with each one another.

The AFCOLR annually publishes the Air Force Logistics Research and Studies Program document. This document contains current or projected operated and support deficiencies of Air Force weapon systems as identified by Major Air Commands.

The Logistics Research and Studies Program document is used by Air Force System Command (AFSC) to establish research and development programs which address the operation and support deficiencies. Offices assigned under AFSC, managing programs specifically addressing the logistics needs, are located within the AFWAL. AFWAL is composed of four individual laboratories (materials, avionics, propulsion, and flight dynamics) whose mission it is to provide the technology needed for future Air Force systems and to assist the Product Divisions of the AFSC in acquiring new systems and resolving developmental problems.

Another organization within the AFWAL is the ILTO. The ILTO is the Air Force advocacy center for logistics technology in the laboratories and is responsible for logistics technology transfer.

AFCOLR, AFWAL, and ILTO are all located at Wright-Patterson AFB. This allowed for personal interviews of project engineers chosen by a senior official within each organization. The project engineers were chosen for their expertise and knowledge of particular technologies. Personal interviews were preferred because they could be longer than telephone interviews. Each interview discussed a number of different technologies requiring considerably more time to develop an understanding of the objectives and applications of each than would have been practical in a telephone interview.

The project engineers were asked questions in their area of expertise: airframe structures; avionics; flight controls; materials; and power systems. The aim was not to interview a defined number of people to have a valid statistical sample, but rather to interview people with the knowledge of their organization's specific programs addressing supportability issues or programs which should address these issues.

## Information Processed

Information gained from the interviews included: how the research was addressing supportability issues; objective and scope of the programs; applications for the new technology; timeframe when the technology would available for use in operational aircraft; how supportability was defined and measured; and the level of emphasis supportability was receiving in the program. Areas of aircraft systems which lacked supportability research were identified.

## III. Presentation of Results

### Research Questions

Question One. What contracting strategies exist or should be implemented which would give equal consideration to supportability, cost, schedule, and performance in the acquisition process?

Results. This research investigated four acquisition strategies which could be implemented by acquisition program management to increase the level of emphasis placed on supportability in aircraft system design: (1) competition, (2) quantified supportability tradeoffs, (3) military specifications, and (4) standardized terminology.

Competition. Cost alone should not be the objective of competition. Competition should also be used to increase attention to other aspects of the aircraft system. Panelists at an Aerospace Education Foundations Roundtable held in 1986 concluded that such things as reliability and maintainability are other aspects of aircraft systems that must be competed (9:55). Technical innovation, reliability, producibility, maintainability, and life cycle costs all enter into the definition of competition. All of these factors must be weighed in the balance, particularly in modern aircraft systems which are usually on the cutting edge of advanced technology (24:22).

In a 1974 study the effect of competition on cost of aircraft replenishment spares was investigated. The study concluded that the net savings from changing from sole-source to competitive procurements was a function of the sum of saving realized in procurement dollars, procurement data costs, administrative costs, quality costs, and reliability costs. Net savings as a percentage ranged from 10.85 to 17.5 depending on the quantity purchased. The upper value of 17.5 percent was associated with larger quantity purchases (11:82).

For the acquisition program manager, acquisition streamlining offers the potential benefits of increasing competition by removing detailed (how-to) specifications and standards before development of the design. In the past, contract awards have been based on who demonstrated the most knowledge of and compliance with these specifications and standards without necessarily demonstrating the best design proposal. The multitude of specifications and standards inhibit the tradeoffs necessary to achieve overall system objectives (such as affordability, producibility, and supportability) and contribute to suboptimum design and unnecessary acquisition costs (48:16).

Streamlining is a new approach in which the definition of detailed technical requirements is considered an integral part of the design and development process. In the past, these definitions were made in the proposal phase when there was a lack of knowledge on the specifics of the design. Under the streamlining approach, definition of technical requirements is most properly treated as an element of contract performance rather than an element of contract definition (49:5). Policy guidance on acquisition streamlining is contained in DOD Directives 5000.43 and 4120.21 and DOD Handbook 248B.

Quantified Supportability Tradeoffs. A problem faced by the Air Force and industry is how to maximize operational readiness and minimize logistics support costs. This is difficult to do because the supportability characteristics of each aircraft system/subsystem affecting readiness are uncertain (45:33). Logistics Assessment Methodology Prototype (LAMP), and simulation models, are available for use by the SPO and the contractors to reduce the uncertainties in quantifying supportability requirements.

LAMP is a computer based methodology to qualitatively evaluate specific technology applications and quantitatively evaluate its supportability characteristics. The goal of LAMP is to influence design so the operational objectives of the weapon system may be achieved while optimizing the use of constrained supportability resources such as manpower, support equipment, and cost. The Logistics Assessment Work Station (LAWS) provides the capability for acquisition logisticians and other decision makers to query LAMPs for concise answers to their many design and supportability questions.

Accessing information from LAMPs through LAWS, users may now quickly modify design characteristics, adjust operational requirements, compare design alternatives, and generate tradeoffs and sensitivities to reflect equal consideration of supportability, cost, schedule, and performance (15:8).

The successful application of LAMP/LAWS depends on its integrated use by the SPO, contractors, and the integrated logistics systems (ILS) management team. The ILS team is a group within the SPO manned by acquisition logisticians concerned with support optimization. LAMP needs to be made a contractual requirement to be used by all agencies involved in the design and acquisition of new weapon systems (46).

The qualitative portion of the LAMP methodology will indicate if it is cost effective to pursue the analysis and proceed with the quantitative evaluation. If the qualitative evaluation indicates application of LAMP methodology is not cost effective, an alternative would be to use simulation models. Simulation models would not provide as thorough an analysis as LAMP. However, simulation models can be developed inexpensively (relative to LAMPs) to provide results quickly and accurately.

Simulation models can be used to quantitatively relate the relationship between supportability for aircraft components. This can be done without actually having to deal with the real world of changing hardware reliability and noting its impact on maintenance and other supportability resources. For example, it is assumed by increasing component reliability, maintenance workload is decreased. Workload includes any activity associated with equipment repair such as: (1) actual equipment repair time, (2) documentation of repair work, (3) locating and ordering spare parts, (4) support equipment set-up, and (5) preparing not-reparable-this-station components for shipment. This relationship between reliability and maintenance workload is based on common sense. However, quantifying the required reliability improvement for a desired decrease in maintenance workload requires more than just common sense. It requires knowledge of the support processes. It requires a relationship be defined between each of the supportability resources. This is necessary to quantify gains and losses between resources as changes are made in the support structure.

A literature search indicated simulation has been used as a means of quantifying these gains and losses. McDonnell Aircraft Company was faced with a problem of how to maximize operational readiness and minimize logistics support costs on the F/A-18. The solution they formulated involved using computer simulation models to predict potential support and formulate simulation models to predict potential support deficiencies, identify spares cost-reduction opportunities, and formulate corrective actions to achieve readiness goals at the least cost. Model analyses provided information to the company's managers of each logistic element enabling them to take steps to head off predicted support deficiencies (45:33-40).

An Air Force Institute of Technology thesis (31) investigated the impact of an effective R&M program on mission capable rates, sortie rates, and maintenance manpower requirements of Air Force weapon systems. It used a simulation model to quantify the effects that improved system R&M had on these other factors.

Simulation modeling could be made a contractual requirement as a means by which SPO management could require its contractors to quantify supportability tradeoffs. The decision to use simulation must be based on validation of the model. Also, the decision must be based on the model's applicability to the elements of interest.

Military Specifications for Supportability. ASD has developed the Avionics/Electronics Integrity Program (AVIP) to enhance the combat capability and operational suitability of weapon systems. This is achieved by improving either the reliability, or the ease and effectiveness of maintenance, or both, for the avionics/electronic equipment portions of the weapon system. AVIP is a means for avionics to meet the goals of R&M 2000.

Avionics are the only systems on aircraft in the Air Force inventory that are maintained with only corrective maintenance. All other systems are maintained with both corrective and preventive maintenance. AVIP will require that a trade study be conducted to determine the cost effectiveness of performing corrective and preventive maintenance on the avionics. The decision will reflect what is most cost effective from the R&M 2000 perspective. The avionics will be maintained with corrective and/or preventive maintenance based on the results of the trade studies (21).

The AVIP has changed the focus of reliability from "it is reliable when it does not break" to statistical descriptions of "allowable" in-service failures. The application of AVIP to future aircraft system acquisitions would require a commitment from the contractor for "Failure free" operations of the avionics for a specified time.

AVIP evolved from other integrity programs for engines, Engine Structural Integrity Program (ENSIP), and for airframes, Aircraft Structural Integrity Program (ASIP). These three programs have produced military standards:

| | |
|---|---|
| MIL STD 1769 | Avionics/Electronics Integrity Program (AVIP) Requirements |
| MIL STD 1783 | Engine Structural Integrity Program (ENSIP) Requirements |
| MIL STD 1530A | Aircraft Structural Integrity Program (ASIP) Requirements |

Future military standards will be published for software, mechanical subsystems, and integrated diagnostics. As acquisition management tools, AVIP, ENSIP, ASIP will be implemented through application of these military standards. The military standards will be required using acquisition streamlined procedures.

Standardized R&M Requirements. Several military standards and handbooks (for example, AFR 800-18, DOD Directive 5000.40, MIL HNBK 217D) have been published to provide guidance to the Air Force and its contractors on particular R&M tasks and requirements. But, none of the documents state what measurements are to be taken to be used to calculate the R&M parameters stated as requirements. Without specific guidance to provide technical understanding of R&M requirements and demonstrate the calculation of R&M parameters, contractors have not been responsive to the R&M requirements established in the statement of work (SOW) of the request for proposal (RFP) (23:39).

The lack of guidance in the R&M arena is a problem during source selection and, also, throughout the life cycle of the weapon system. For instance, to apply LAMP methodology to a particular aircraft system, R&M requirements must be defined to serve as "design to" objectives. If these requirements are not defined to mean the same thing to the contractor and the various Air Force agencies involved in the design of the aircraft system, optimum tradeoffs between supportability and cost, schedule, or performance will be compromised.

On September 24, 1985, the Deputy Secretary of Defense signed a policy memoradum that commits DOD to the objective of transitioning from current paper-intensive design and logistic processes to a largely automated and integrated mode of operation for weapon systems entering production in the 1990's. The Computer Aided Logistic Support (CALS) Program was established to integrate and manage logistic automation efforts toward this objective.

CALS program will result in a DOD and industry-wide design tool and information system for logistics data. CALS will be maintained and applied to all weapon systems throughout their life cycle. Implementation of the concept of the CALS program in conjunction with AVIP, ENSIP, and ASIP requirements could provide the SPO with the acquisition strategies needed to eliminate ambiguity and misunderstandings in the interpretation of R&M requirements (7).

The objectives of CALS are to improve: logistics technical information by applying and integrating data automation techniques and standards; accuracy, timeliness, and utility of logistics technical information; ability of industry to produce weapon systems using computer aided technologies; and operational weapon system support. With both DOD and industry using the same logistics data base, and with logistics information stored and communicated via the computer, consistent terminology and definitions should result.

CALS will encompass many activities of various contractors and DOD agencies. For example, the Air Force has established a management integration office (MIO) at HQ AFSC/PLX to integrate the technical and programmatic activities of ongoing CALS developments, initiate additional efforts where needed, and arrange for the introduction of new information systems into weapon system programs. The Air Force Human Resources Laboratory at Wright-Patterson AFB is responsible for the development of a computer software architecture for integrating logistics data bases into a distributed network of information. Completion of the many CALS initiatives and integration efforts will be concluded by 1995.

Question Two. What current or new technologies will make future aircraft systems more supportable without sacrificing cost, schedule, and performance?

Results. This research investigated eleven advanced technologies which could be retrofitted on existing aircraft systems or included in the design of future aircraft systems to improve aircraft system supportability:

1. VHSIC
2. PAVE PACE
3. Self-repairing flight controls
4. Fault-tolerant power systems
5. Ultra reliable radar
6. Software
7. Advanced structures
8. Transparencies
9. Landing gear
10. Cockpit displays
11. Engines

The selection of technologies in this thesis was based on a qualitative evaluation of the potential contribution of each technology to eliminate the problem areas and deficiencies identified by the High Reliability Fighter Study, Air Force R&M 2000 goals, logistics needs, Air Force Systems Command, HQ USAF, and Air Force Logistics Command. These problem areas and deficiencies were identified in the following discussion of each of the technologies. These technologies were also selected to cover major systems on the aircraft. This was done to demonstrate the extent to which supportability of aircraft systems can be improved by the appropriate application of advanced technologies.

The application of technologies selected had to result in at least one of the following: increased reliability, decreased need for support requirements (i.e., maintenance manpower, support equipment, etc.), or decreased maintenance repair time.

> We're on the threshold of something marvelous in aviation. The era of the starfighter is upon us. I'm not talking about technologies of the year 2100. I'm talking about technologies that are with us right now [4:43].

The following is a review of these selected technologies and their supportability features.

<u>VHSIC</u>. The defense posture of the United States (U.S.) is increasingly based upon the concept of a military force that is technologically superior to any potential

adversary. The U.S. uses technology wherever possible to ensure its ability to defend against numerically greater forces. The technology of the integrate circuit has become the foundation of the complex electronic systems that are employed as force multipliers in our Nation's defense (53).

In the past, the U.S. was able to maintain a comfortable lead in the military applications of integrated circuits. However, by the late 1970's it became apparent that our "comfortable" lead had seriously eroded. As a result, the ability of the U.S. to maintain a superior military force assisted by the earlier access to advanced electronics technology was in question.

One of the major reasons for this erosion of capability was that it was taking longer and longer for the DOD to move high performance integrated circuits (ICs) from the development phase into military system applications. As a result, military weapon systems were becoming technologically obsolete before their useful life had been expended. This jeopardized the security of the U.S. and resulted in higher defense costs.

In 1978, DOD initiated VHSIC (very high speed integrated circuit) as a tri-service program. The goal of the VHSIC program is to drastically reduce the delay experienced by the DOD in getting advanced, state-of-the-art ICs into military usage. The VHSIC program has been structured to do this within two IC generations.

The first generation of ICs was completed in 1985 with their insertion into an operational weapon system, the AN/ALQ-131 electronic warfare system. This generation of ICs operate at clock speeds of 25 MHz and have an average of 20,000 logic gates per chip. The dimensions of the ICs are no larger than 1.25 microns.

Development efforts on the second generation of ICs began in 1984 and are scheduled for completion in 1988. The second generation of ICs must meet the following specifications: operate at 100 MHz; contain from 75,000 to 5 million logic gates; size of .5 microns; and failure rate of .006 percent/1000 hours.

VHSIC enhances not only system effectiveness but also system supportability. VHSIC improves reliability through part count reduction by requiring fewer boards to perform a function. Also, VHSIC reduces the number of interconnections with larger, more densely packed ICs. (To a first approximation reliability is inversely proportional to the number of interconnects in a system.) Maintainability is improved through the use of built-in test on the ICs. Ten to 30 percent of IC logic is devoted to diagnostics. With better built-in test capabilities offered by VHSIC, requirements for test equipment are reduced.

Reduction in the size of systems incorporating VHSIC reduces power requirements. Programmability of the system is easier with VHSIC because more circuitry is available for logic and memory. This means that missions can be modified by software program changes, rather than replacing hard wired equipment. Modifying software programs can be done more easily and at lower cost than replacing hard wired equipment.

As part of the overall VHSIC effort, the VHSIC hardware description language (VHDL) program was initiated to establish an industrial standard for the documentation of the VHSIC process and products. VHDL will define chip performance as required by the military. This will allow a contractor to design new ICs and use different technologies to build them but IC performance must follow requirements of VHDL. VHDL can be given to any contractor to build an IC. The existence and application of VHDL eliminates the problem of sole source procurements and not being able to procure spares (50; 58).

PAVE PACE. The AFWAL Avionics Laboratory has been working since the 1970's to improve the supportability of aircraft avionic systems. Their first program, digital avionics information system (DAIS), eliminated 57 different data processors from the Air Force inventory with the development of a common data processor. Common data processors are now used to perform the functions of the previous 57 different data processors. The common data processor stopped the proliferation of instruction sets and support software that had been needed for each different data processor. With the common data processor, one set of support software is used to develop the operational flight program software. Also, only one instruction set, defined in MIL STD 1750A, directs how data is to manipulated and stored by the common data processor.

The PAVE PILLAR program was a fallout of the DAIS program. PAVE PILLAR was developed to support aircraft operations from deployed locations with a minimum of support. PAVE PILLAR developed line replaceable modules (LRMs) in avionic hardware to support a two-level maintenance concept (flightline and depot). Under the PAVE PILLAR program, the common signal processor was developed with the same advantages as the common data processor.

The thrust of the DAIS and PAVE PILLAR programs was to develop standards which all new avionics systems have to meet. This means that as technology advances and new avionics designs result, these designs can be easily integrated into existing avionics architecture with minimal changes or disruption to system operation and support.

DAIS and PAVE PILLAR addressed standardization and modularity of avionic systems. The next step was to address reliability and fault-tolerance.

The PAVE PACE program is being initiated to take advantage of new technology to improve the performance and supportability of future avionics. Only the supportability aspects of this program will be discussed further.

Two of the goals of the PAVE PACE program are the improve the reliability and fault-tolerance of the avionic systems. Advanced technologies will be evaluated for their contribution to meeting these goals.

PAVE PACE will consider the effects of the following environmental factors on avionics reliability:

1. Vibration--it can cause connector problems.

2. Temperature cycling--it can destroy chips.

3. Dirt/sand contamination--it can impact the perfect fit of modules in an avionics box. If modules mate improperly, extreme heat can be generated or pins can be broken.

4. Electromagnetic impulse (EMI)/lightning--it can disrupt/destroy electrical signals and equipment.

5. Maintenance handling--it can cause breaks in electrical connections.

It is these factors which PAVE PACE will attempt to overcome or eliminate with the application of advanced technologies. For example, electrical communication through metal could be replaced with optical communication through material other than metal to overcome the effects of EMI/lightning. Wire-to-wire connections between circuit chips could be eliminated with photolithography techniques to overcome vibration problems. Circuit chips could be glued down instead of bonding chips with metal wire to the printed wiring board. This could overcome more vibration problems.

A fault-tolerance scheme will be investigated to monitor the health of all circuit chips. Certain chips would be designated to detect the failure of the remaining chips and to switch chips on and off as needed. This is an idea that is being conceptualized to allow for deferred maintenance without loss of operational effectiveness.

Self-Repairing Flight Controls. The F-15 and F-16 flight control systems (FCS) are characterized by: (1) many failures, an average of one every 35 hours, (2) complex actuators that make up 50 percent of the life cycle cost of the FCS, and (3) difficult maintenance, an average of 8.3 hours to diagnose problems. Reported failures on the F-15 and F-16 FCS result in maintenance personnel not being able to duplicate failures on 31 percent of the maintenance actions. Another 34 percent of the maintenance actions are removals of serviceable items; components which check out okay in the shop. The true FCS failures, at best, result in mission aborts. One-half of the F-15 and F-16 mission aborts are due to the FCS. The next generation of aircraft such as the Advanced Tactical Fighter (ATF) could have a self-repairing flight control system (SRFCS) to overcome the problems associated with current FCS.

A self-repairing flight control system refers to a flight control system that can tolerate failures. Loss of the aircraft can be avoided by activating other control surfaces to perform in unconventional configurations thereby compensating for the failed component of the flight control system.

The AFWAL Flight Dynamics Laboratory is responsible for the development of the SRFCS. The SRFCS will include all control surfaces, on an as needed basis, to complete the pitch, roll, and yaw motions of the aircraft. An on-board computer will be used to provide a real-time reconfiguration of control surfaces as failures occur or battle damage is sustained by any part of the FCS.

Control surfaces can often function in more than one capacity. Real-time computerized reconfiguration will take advantage of this capability and provide aerodynamic redundancy for the aircraft. This redundancy of control surfaces eliminates the need for redundancy of servo-electronics in the actuators driving the control surfaces. Eliminating the redundant servo-electronics not only reduces part count but, also, reduces the complexity of the actuators.

Aerodynamic redundancy may be explained by example. An aircraft sustains damage to its rudder. With the SRFCS, the computer senses the degraded capability of the rudder. When the pilot indicates a turn to the right is to be made, the computer decouples the roll function of the trailing edge wing surfaces. The computer then signals the ailerons on the right wing that one aileron is to deflect up and the other down. (The other ailerons are left in a standard setting.) In this way, the ailerons are used to create the yaw necessary for the turn the rudder is unable to generate.

The SRFCS program will be completed in 1994. Over the next seven years many issues will be addressed such as developing and demonstrating aerodynamic control laws, the strategy for fault detection and isolation of multiple failures, and degrees of failure under various flight conditions.

The SRFCS can be operated with the existing electrical/hydraulic system not used or in the future with an electrical system. The SRFCS will be applied to fighter aircraft and later transitioned to larger aircraft. It will be designed to be maintained with only two levels of maintenance: flightline and depot.

The Flight Dynamics Laboratory has shown through analysis that FCS improvements on the next generation fighter could be: increased MTBF to 350 hours; reduced operation and support (O&S) costs by 30 percent; reduced maintenance manhours per flying hour (MMH/FH) by 80 percent; and reduced maintenance actions per failure from 3 to 1.2. These improvements would be realized with the application of the SRFCS using innovative technologies such as expert systems for maintenance diagnostics and reconfiguration (43).

Fault-Tolerant Power Systems. In aircraft of the year 2000 and beyond, anything previously done pneumatically or hydraulically will be done electrically to reduce weight and life cycle cost. These future electrical systems will provide power to such things as fuel pumps, air conditioning systems, and computers. They will replace the hydraulic systems now use for actuation. Because the majority of operations performed ont he aircraft will depend on the electrical systems, these systems must be fully reliable.

To meet this challenge, the Fault-Tolerant Electrical Power System (FTEPS) program was initiated by the AFWAL Aero Propulsion Laboratory in 1985. The objective of the program is to develop an electrical power general and distribution system which will supply electrical power to critical systems on the aircraft. It will have reliability and power quality level commensurate with the requirements of flight critical, mission critical, and non-flight critical loads. Loads refer to those subsystems being supplied with power.

Operation of the FTEPS will require minimal pilot action. Limited hardwired controls will be provided for emergency override and for maintenance functions. No pilot interaction will be required during normal system operation.

Primary system control will come from the power system processor (PSP). The PSP will maintain complete system status information and provide these data for display to the pilot through the avionics. The avionics will transmit the flight phase status, as well as a matrix of Boolean expressions, representing the desired on/off state of each load to the PSP. The PSP will use this information to implement the load control and load management functions. The load management function will ensure that maximum use is made of the existing system generating capacity by matching load complement to the capacity and flight phase. The PSP will calculate priority level according to the generating capacity and the flight phase. The priority level and power requests will be implemented (57).

Faults in the electrical system occur for a number of reasons. Adequate protection and controls to prevent propagation of these faults within the system will be incorporated. Fault isolation and protection will be required to keep the other normally operating electrical power channels from being affected and to provide system status to the PSP. The fault isolation capability will be available whenever the power system is operating. Information from fault isolation is available to maintenance personnel thus simplifying the task of system diagnostics and reducing the need for support equipment.

Current power systems use a large number of cables and connectors. The application of the FTEPS eliminates many of these (for example, 15.5 miles of wire on the A-7D) by replacing them with a multiplex data bus.

The advantage of redundancy is gained from switching or reconfiguring the power system between subsystems as demands for power change. This redundancy results in a decreased probability of power failure. It is expected that the probability of power failure will be 100 times less than the probability of load failure.

The majority of the technology used in the FTEPS program is currently in place. What remains to be developed outside of this program is solid-state power controllers which supply above 10 amps. What remains to be done on the FTEPS program is system integration and writing the computer software for controlling the power system (56).

Ultra Reliable Radar. To successfully meet the warfighting requirements in the year 2000 and beyond, the Air Force has projected a need to operate its fighter aircraft from widely-dispersed, austere bases where little or no maintenance support will be available. This means that internal systems must be able to store failures and defer maintenance as long as possible. The radar system has been a high failure item in current aircraft systems such as the F-15 whose radar had a MTBF as low as 40 operational hours in the 1980's. The radar subsystem requires considerable improvements in reliability and maintainability if its host aircraft is to operate from remote/austere bases. The AFWAL Avionics Laboratory is funding a program to do just that. The Ultra Reliable Radar (URR) program is to develop the next generation radar technology which will be applicable to the ATF and F-15/F-16/B-1B update programs.

Increasing availability and lowering support costs are two main objectives of the URR program.

Major subsystems of the URR are the common signal processor (CSP), solid-state phased array antenna (SSPA), and receiver/stalo (stable local oscillator). The CSP is used by the URR as a general purpose signal processor. The processor is designed in accordance with MIL STD 1750A to be used in electronic warfare, communication/navigation, radar, or electro-optic applications. The URR development will capitalize upon the solid state phased array technology and very high speed integrated circuit (VHSIC) technology. These and other emerging technologies will be integrated into a fault-tolerant architecture which is capable of being supported by two levels of maintenance (flightline and depot). This is expected to yield a radar whose reliability of 400 hours MTBF is 10 times that of today's F-15 radar.

Reliability improvements will be achieved by including redundant line replaceable modules (LRM) in the CSP and receiver/stalo. The redundant LRMs replace failed LRMs during automatic reconfiguration. Reconfiguration is the same type of strategy used in the fault-tolerant power system and self-repairing flight control system. Reconfiguration is controlled by integrated BIT/FIT (built-in test/fault-tolerant test) and reconfiguration software in an on-board computer.

Maintainability improvements include deferred maintenance for enhanced supportability at austere sites. This is achieved through automatic reconfiguration and fault-management software. Also, graceful degradation is designed into the SSPA to reduce maintenance requirements. Up to five percent of the SSPA modules can fail and yet still allow the SSPA to meet military specifications. BIT/FIT will decrease the time it takes for maintenance personnel to perform system diagnostics and reduce the need for support equipment. This program is evaluating the application of time stress management devices for the resolution of "retest ok" and "cannot duplicate" at the depot maintenance level (37).

<u>Software</u>. Typically, supportability of aircraft systems has been concerned with hardware. This is changing as software consumes more and more of the DOD budget (currently 10% and growing exponentially). The ultra reliable radar, self-repairing flight control system, and fault-tolerant power system are examples of increased use of software. Entire fleets of aircraft grounded for a software error require a closer look be taken at software supportability.

It has to be expected that software will be replaced, added to, and/or changed over the lifetime of the host aircraft. In the 1970's, as the aircraft mission, threat, or hardware changed, software was modified by changes made to an entire software program. Even to correct for an error, many changes were required throughout the software program. This was costly and inefficient. The original software and any modifications were also poorly documented making changes even more difficult.

The Air Force realized from its experiences in the 1970's that software must be designed to be supportable. Tradeoffs between performance factors such as speed of processing and supportability factors such as modular coding were a necessity. With modular code, an error could be corrected by a change to a software module rather than to the entire software program.

The Defense Department has an initiative to design a computer superlanguage called Ada. It may be the solution to the software supportability problem experienced by the Air Force and other services. It is expected to save the Pentagon billions in software maintenance and software inventories. It would replace as many as 400 distinct languages throughout a whole range of applications--everything from automatic data processing (ADP) to internal guidance to other embedded weapon systems to artificial intelligence. It would be machine-independent, portable, and easy to maintain (33).

Ada is a high order language (HOL) that i  user friendly. It is replacing machine code and assembly languages which are much harder to document then Ada.

Two new DOD directives were issued in March, 1987, that make Ada mandatory for all new or upgraded weapons and ADP software. The DOD's Ada Joint Program Office readily admits that while the directives are in place, there are still stumbling blocks. Many system program managers have found ways to stall Ada's advance either by getting waivers from the directives or by drafting their request for proposals (RFPs) in such a way that Ada is not suitable.

Virginia Castor, Director of the Ada Joint Program Office, says much of the blame for Ada stonewalling has to lie with industry. "It's not so much that the program manager has slowed Ada down. He's being influenced by contractors looking to protect their research and development (R&D) funds." DOD owns the copyright on Ada and therefore precludes many contractors from claiming R&D reimbursements for their software tools, Ms. Castor says. As a result, "it's the contractors who convince the program managers that Ada won't work for their applications," she adds. "And once the program manager is sold off Ada, the contractor can sell him on software packages owned by the contractor" (33).

If Ada is to be used, support software is required to mesh the software code in the HOL with computer hardware. The advantage gained from support software is that software code can be written independent of its hardware application. This means that any contractor can now write software for the Air Force. Whereas, in the past, software could be written only by the contractor who supplied the hardware (35).

Advanced Structures. In 1981, the Air Force Logistics Command started sending operational supportability problems to AFCOLR in the form of logistics needs. The logistics needs which deal with aircraft structures are forwarded by AFCLOR to the AFWAL Flight Dynamics Laboratory for a solution. Structural improvement of operational aircraft is an on-going program initiated in 1981 by the Flight Dynamics Laboratory to develop structural components with optimized supportability characteristics. These new structures are targeted as replacements for structures causing the operational supportability problems.

Under the structural improvement of operational aircraft program, a new center section leading edge flap for the A-7 was developed. The original flap had an average service life of 1360 hours. An investigation of the mission environment of the A-7 revealed vibration was the cause of early flap failures. The redesigned flap has an expected service life of more than 100,000 hours. The increased life is achieved with the application of integral damping technology and a redesign of the internal flap structure.

Integral damping technology is a process whereby an adhesive and metal are bonded together to dampen vibration. Metals have no damping properties and transfer any vibration throughout the entire structure. When metals are bonded to an adhesive with viscoelastic damping properties, the vibration is absorbed by the viscoelastic material. This minimizes the amount of vibration transferred to the remaining structure.

Another structural improvement effort is on the F-111 outboard spoiler. The original design of the spoiler have been made in the 1960's before sound waves were considered as a source of acoustic vibration. A redesign of this part incorporating integral damping and superplastic forming technologies increased service life from 1,400 to 98,000 hours and reduced piece parts by 93 percent.

Superplastic forming is a manufacturing technique to form parts into detailed final shapes. The forming is done under high pressures and temperatures. Finding the correct combination of temperature and pressure under which to do this forming is a difficult task. To date it has been successfully accomplished with aluminum and titanium.

Parts are typically manufactured into complex shapes by joining a series of smaller and simpler metal pieces with rivets and fasteners. The built-up structure is susceptible to corrosion and fatigue damage.

Superplastically formed structures offer many supportability advantages. These structures reduce parts count by eliminating the need for fasteners and rivets to manufacture complex shapes. Reduced parts count, in turn, decreases maintenance task time. Another benefit of superplastically formed structures is their corrosion resistance. These integral structures are water impregnable. Also, the absence of rivet and fastener hole eliminates the potential fracture sites where fatigue cracks originate.

The Flight Dynamics Laboratory is also sponsoring the supportable hybrid structures program. Under this program, supportability improvements are coequal to performance and cost. The program will establish a data base for aircraft material selection based on least cost, most supportable, and best performance to be achieved for a given application. The program will evaluate the supportability aspects of: advanced materials; composites and metals; joining methods; aircraft battle damage; manufacturing techniques; superplastic forming; and repair procedures for peace and wartime. This program is targeted for completion in 1991. The results will be given to the ATF SPO (6; 41; 42).

<u>Transparencies</u>. In the early 1970's, the Air Force was losing, on the average, one F-111 every eleven months. The cause was due to birds striking the canopies. Transparencies were then developed to keep birds from damaging canopies but these had poor optical qualities. Pilots could not see through the canopy well-enough. Another development effort was funded to improve optical quality. The difficulty with these independent efforts to

address individual problems was that an optimum canopy design was never realized.

Canopies are composed of a frame and transparency. The transparencies are formed as a composite. Each later of the composite serves a particular purpose. For example, one layer may be for protection against laser hardening with another layer to improve optical quality.

The F-111, F-16, T-38, F-4, A-7, and B-1 have all required retrofit canopies. This is because of a mismatch between the transparency qualities which were needed to fly the mission. Each aircraft requires a transparency with a certain set of qualities which include any or all of the following: hail, lightning, and birdstrike protection; laser, chemical, and microwave hardening; radar cross section reduction; optical quality; and cost of ownership.

The AFWAL Flight Dynamics Laboratory recognized that transparency technologies cannot be developed to solve individual problems independent of the overall requirements of the aircraft mission. The problems had to be solved with all factors considered. The mission integrated transparency system (MITS) program was sponsored by the AFWAL Flight Dynamics LAboratory to develop an optimum transparency. The program is to blend specific technologies together to meet the requirements of a given mission. The technologies will come from lessons-learned on past transparency retrofit efforts. An optimum transparency will consider the needs of both the aircrews and the maintainers.

The objectives of the MITS program are to improve optical qualities of, increase life of, and reduce the cost of transparencies. Also, easier maintenance procedures will be developed. This will results in a transparency which represents a good balance between supportability and performance features.

Also, under this program, the metal frame for the transparency will be replaced by some type of hybrid composite (for example, kelvar/glass epoxy). The composite frame has potentially many advantages over the metal frame. The composite frame will be less expensive and lighter weight. In the past, the metal frames were only supplied by airframe contractors. This made spare parts hard to get. A variety of sources for the composite frame exist to manufacture the frame and to provide spare parts.

The MITS program is projected to be completed by 1995. At that time, the canopy designs for an air-to-air fighter and air-to-ground fighter will be complete. The procedures will exist to design canopies for other aircraft and missions (22; 47).

<u>Landing Gear</u>. Landing gear must be overhauled frequently due to corrosion of structural components. The overhaul facility for landing at Ogden Air Logistics Center cites corrosion as the number one reason for condemnation of

landing gear components. The preventive maintenance schedule for C-141 landing gear is driven by corrosion requiring overhaul every two years. These condemnations and requirements for frequent preventive maintenance are drivers to replace corrosive metals with noncorrosive advanced materials.

The AFWAL Flight Dynamics Laboratory is managing a program, Low Life Cycle Cost Landing Gear, to investigate the eventual replacement of 300M high strength steel and aluminum with titanium matrix composite (TMC) landing gear components. A very high strength material is needed for landing gear. Titanium has been built-up as a metal matrix composite to achieve that strength. The objective of the Low Life Cycle Cost Landing Gear program is to verify: it is possible to fabricate landing gear components from TMC; TMC is strong enough; it can be mated to other components of the landing gear. It is anticipated TMC will have a higher acquisition cost but much lower operation support (O&S) costs so overall Life Cycle Cost will be lower with TMC than with conventional landing gear materials.

One major benefit of TMC for landing gear structural components is the potential it offers to reduce the number of both scheduled and unscheduled maintenance actions. This could potentially increase reliability by 30 percent. The number of scheduled maintenance actions are decreased by reducing periodic inspection for structural integrity and for corrosion. The number of unscheduled maintenance actions are decreased by reducing failures due to fatigue, overstress, and stress corrosion.

When a TMC component is removed for repair or inspection, a number of current maintenance procedures can be omitted because of titanium's noncorrosive properties. In complex areas, considerable desassembly is required to inspect for corrosion. This is especially serious in lubrication passages, threaded connections, lug faces, and press fit joints. During overhaul, all paint and surface finishes must be removed to inspect for corrosion, and corrosion inspections, become unnecessary. Finally, corrosion removal, done by air-powered equipment, hand polishing, or machining, is also eliminated.

Maintainability of TMC landing gear improves because of fewer and simpler maintenance procedures. Although no quantifiable data can be developed at this time for maintenance reduction, it should be at least comparable to the reliability improvement.

Another aspect of this program is an investigation of how to reduce periodic maintenance. It consists of developing an advanced landing gear system and its components. The following parameters may be measured by this system and displayed to both aircrew and ground personnel: tire, strut, antiskid brake, and arresting hook damper pressures; strut oil level; brake wear; brake temperature; and weight and balance information. This system will be available in the mid-1990's for aircraft application (36).

Another technology the AFWAL Flight Dynamics Laboratory is investigating for the High Reliability Fighter is radial tier designs. Radial tires provide longer life, require less maintenance, and offer reduced weight over current bias tires. Designs exist for select aircraft but this is not yet a mature technology (36).

Cockpit Displays. There are thousands of bits of information needed by the military pilot to fly today's sophisticated aircraft. Mechanical needle indicators require an excessive amount of space in the cockpit to display all required information. These mechanical indicators also do not display the information in a format that is easily read by a pilot constantly bombarded with information. What is needed is graphic display of information for the pilot to read more quickly.

Cathode ray tubes (CRTs) replaced mechanical needle indicators to provide graphic displays. But CRTs still required too much space in the aircraft and they were not reliable. The life of CRTs in operational aircraft ranged from 200 hours to 2000 hours and they failed catastrophically (they either worked or they did not work). In an attempt to overcome the shortcomings of mechanical needle indicators and CRTs, the AFWAL Flight Dynamics Laboratory has been investigating alternative technologies.

The alternative technologies are light emitting diodes (LEDs), liquid crystals, electroluminescence, and flat panel CRTs. These technologies can be packaged into "flat" displays requiring only one-fifth the area occupied by conventional displays. The alternative technologies can function in the capacity of multifunction displays. This further reduces the number of separate display units in the cockpit and makes more efficient use of the display units used (34).

An LED is in principle a simple semiconductor device. LED display devices are used in commercial applications such as hand-held calculators and watches. LED displays are suitable for aircraft and other military applications in part because of their high reliability. The MTBF of an LED flat panel display is estimated at 10,000 hours. The LED display generally fails gradually, as opposed to the catastrophic failure which can occur with tube displays. LEDs can be constructed of arbitrary size and shape. The major disadvantage of flat panel displays is their higher power consumption (51:289-331).

A liquid crystal display (LCD) is a nonemissive display normally viewed in reflection. This means that there musty be a reflecting medium behind the display. Its function is to return light to the viewer so that he can perceive changes. Nonemissive displays have two basic advantages over LEDs: (1) they require much less power to operate, and

(2) they do not wash out in high ambient light. The term washout refers to the loss of contrast in a light-emitting display. Disadvantages associated with LCDs in military applications are: poor brightness; limited sharpness; limited color capacity; and low reliability (51:415-457).

Flat CRTs are devices which use an electron beam hitting a phosphur as the method of light generation. Thus, all such devices must have a method for generating the electron beams. This portion of the device is called a cathode. The technology for flat CRTs is limited by the capability to miniaturize the cathode. There are many advantageous characteristics of flat CRTs which makes its development worthwhile. Their speed of response and resolution are capable of satisfying the requirement of a pilot for the presentation of high-quality, dynamic imagery. They have few parts and require as little as seven connections. The CRTs are versatile--one design can be used for a wide number of applications with little or no design change. They are reliable, have long life, are relatively inexpensive, and fabrication of the tube is amenable to mass production (51:138-236).

Electroluminescence (EL) is the emission of light from a polycrystalline phosphur solely due to the application of an electric field. It is of simple construction resulting in lower production costs than competing technologies. EL is characterized by low power requirements, graceful degradation, and long life. The disadvantage of EL is poor readability in sunlight (51:237-287).

Each of these technologies is being researched for applications in retrofitted and next generation aircraft systems. These application include: Cockpit and helmet-mounted displays; switches; and lighting inside the aircraft.

Engines. The AFWAL Aero Propulsion Laboratory has an Advanced Technology Engine Gas Generator (ATEGG) program which tests new technologies to demonstrate they will operate as expected in the hostile engine environment. The ATEGG's have specific performance goals to meet with supportability being a desired outcome. There is no "ultra reliable" engine effort under ATEGG but some of the new technologies in ATEGG could result in a more supportable engine.

Three technologies developed by engine contractors or other countries are being transitioned into ATEGG. These technologies are undergoing testing because they offer significant performance improvements but they also offer some significant supportability improvements.

1. Dry Tube Bearings. The bearings are made of nonmetals such as ceramic or glasses. These bearing eliminate liquid lubrication requirements and offer the potential of operating temperatures to 1500°F compared to the 350°F limit currently imposed by liquid lubricants. Elimination

of liquid lubrication means one less servicing requirement imposed on maintenance personnel. The technology availability date for dry lube bearings is the year 2000. They will begin testing in ATEGG by the early to mid-1990's.

2. Ceramic materials. Application of these materials in engines will allow operation at higher temperatures without the need for cooling. Turbine blades and vanes are prime candidates for the application of ceramics. Currently, such blades and vanes are cooled by air passed through a multitude of cooling holes machined into the blade or vane. This results in an expensive and life limited (the cooling holes represent fracture sites) component. With the use of ceramics, these blades and vanes no longer require cooling, and become less expensive to fabricate, and increase the life of the component. Ceramic components will be available for test in ATEGG by the late 1990's.

3. Brushed seals. This technology is replacement for knife edge and face seals. Brushed seals are "super" stiff enabling them to withstand overloads while maintaining tight clearances. Seals are a frequent remove and replace item in engines. Brushed seals offer the potential for reducing, remove and replace maintenance actions because of their longer useable life. This technology will be tested in ATEGG in 1988. It is projected to be in production early in the 21st century (26; 27).

## IV. Conclusions and Recommendations

Aeronautical Systems Division is procuring more aircraft systems in 1987 than ever before: the National Aerospace Plane, the Tactical Fighter, the F-15E, the F-15C and D, the Air Defense Fighter, the C-17, the Advanced Tactical Bomber, and the T-46 or some variant of it. Emphasis on supportability is of paramount importance to ensure these future weapon systems provide the Air Force with maximum capability.

Acquisition strategies such as acquisition streamlining and simulation modeling can be used by SPO management to help ensure supportability is considered equally to cost, schedule, and performance. Other acquisition strategies, CALS, and LAMP/LAWS will be available in the near future to improve the supportability design process.

Each of the Air Force Wright Aeronautical Laboratories has contracted programs to address some aspect of supportability as a result of Air Force changes in mobility and survivability requirements and R&M 2000 initiatives. The programs address technologies which could result in: improvements in the areas of system diagnostics, maintainability, and reliability; reduced need for manpower and support equipment; decreased radar time; and elimination of the intermediate level of maintenance. As these technologies develop, they will do more than just improve supportability. They will stimulate ideas for new technologies and new aircraft. VHSIC technology was originally developed to improve the performance of data and signal processors. During VHSIC development, supportability of weapon systems became important. VHSIC technology was then viewed from both a performance and supportability perspective. As a result, reliability improvements were realized in such programs as the ultra reliable radar which uses the VHSIC technology. The smaller ICs used on this radar results in extra space to include additional ICs for redundancy. The SRFCS benefits from the new supportability perspective of VHSIC by using it to develop an advanced system diagnostics capability. SPOs should view all advanced technologies from both a supportability and a performance perspective to maximize the payoff to be realized from the technologies.

Developing advanced technologies to improve supportability may significantly change the design of future aircraft. Application of the SRFCS may be one of those technologies which will precipitate a radical change in aircraft design. The self-repairing flight controls may be more efficient when used in reconfiguration conditions if changes are made to the function, location, and design of aerodynamic control surfaces.

Advanced technologies should be followed by the SPOs as the technologies continue through advanced development programs and await inclusion in the design of future aircraft systems. Supportable aircraft are possible when technologies are designed to be supportable and when these technologies are transitioned early into the design phase of aircraft systems.

## Bibliography


1. Bornhoft, Maj Stewart H. "Force Multiplier - Useless Cliche or Useful Concept?" Military Review, 63: 2-8 (January 1983).

2. Borg, Walter E. and Meredith D. Gall. Educational Research: An Introduction (Second Edition). New York: David McKay Company, 1976.

3. Boyle, Edward and others. "The Aircraft Maintenance Workforce Now and in the Twenty-First Century," Air Force Journal of Logistics, 9: 3-5 (Fall 1985).

4. Canan, James. "Era of the Starfighter," Air Force Magazine, 70: 42-52 (August 1986).

5. -----. "USAF in the Twenty-First Century," Air Force Magazine, 69: 47-52 (August 1986).

6. Carteauz, 1Lt Mark, Aeronautical Engineer. Personal Interview. AFWAL/FIBAC, Wright-Patterson AFB OH, 29 July 1987.

7. Coleman, Lt Col Joseph, Chief Acquisition Logistics Branch. Personal interview. AFRHL/LRA, Wright-Patterson AFB OH, 6 May 1987.

8. Compendium of Authenticated Systems and Logistics Terms, Definitions and Acronyms. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, April 1981 (AD-A100 655).

9. Correll, John T. "The Pros and Cons of Competition," Air Force Magazine, 69: 54-55 (February 1986).

10. Courter, Jim. "Rx for Defense Procurement," INC, 6: 13-15 (June 1984).

11. Cunningham, James A. and others. A Cost-Benefit Analysis of Competitive Versus Sole-Source Procurement of Aircraft Replenishment Spare Parts. MS thesis, SLSR-49-71B. School of Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, January 1974 (AD-777 247).

12. Decker, Capt LaRita M. and Stephen J. Guilfoos. Aircraft Availability: An Acquisition Decision Strategy. MS thesis, GLM/82S. School of Systems and

Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1982 (AD-A123 060).

13. Department of Defense. Small Business and Small Disadvantaged Business Concerns. FAR 19.100. Washington: Government Printing Office, 1 April 1985.

14. Department of the Air Force. Combat Support Doctrine. AFM 2-15. Washington: HQ USAF, 13 December 1985.

15. E-11777-U. Logistics Assessment Work Station (LAWS), 6 October 1986. Andover: Dynamics Research Corporation.

16. Feduccia, Anthony J. "System Design For R&M," Air Force Journal of Logistics, 8: 25-29 (Spring 1984).

17. Forte, June. "For R&M the Future Is Now," Air Force Systems Command New Review, 30: 6-7 (April 10, 1987).

18. Fuchs, Capt Ron. "Rx = R&M," Airman, 29: 8-14 (July 1987).

19. Griffiths, Dave and Others. "How to Reform the Pentagon's Wasteful Ways," Business Week: 144-149 (27 May 1985).

20. Guilfoos, Steven, Chief, Logistics Needs Branch. Personal interview. AFCLOR/MEL, Wright-Patterson AFB OH, 26 February 1987.

21. Halpin John, Assistant for Product Assurance. Personal interview. ASD/EN, Wright-Patterson AFB OH, 23 April 1987.

22. Hargis, Steve 1Lt, Program Manager of Windshield Program. Personal interview. AFWAL/FIEA, Wright-Patterson AFB OH, 6 August 1987.

23. Harnen, Capt Daniel E. Developing Source Selection Criteria and Standards for Reliability and Maintainability. MS thesis, AFIT/GLM/LSQ/85S-30. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1985 (AD-A161303).

24. Hayward, John T. "Competition and Weapons," Government Executive, 18: 22-23 (March 1983).

25. Hellman, Peter. "The Fighter of the Future," Discover, 7: 25-50 (July 1986).

26. Hill, Richard, ATEGG Program Manager. Personal interview. AFWAL/POTP, Wright-Patterson AFB OH, 21 July 1987.

27. Jay, David, Supportability Engineer. Personal interview. AFWAL/CDLP, Wright-Patterson AFB OH, 21 July 1987.

28. Kitfield, James. "ATF: Playing by New Rules," Military Logistics Forum, 3: 13-18 (September 1986).

29. Kosan, Jeffrey, System Study Engineer. Personal interview. ASD/XRS, Wright-Patterson AFB OH, 10 April 1987.

30. Kross, Walter. Military Reform: The High-Tech Debate; Tactical Air Forces. Washington: National Defense University Press, 1985.

31. Lewellen, Capt Myron L. A Simulation Model for Determining the Effect of Reliability and Maintainability on Maintenance Manpower. MS thesis, GOR/OS/85D-13. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1981 (AD-A167 146).

32. McCarty, Dyke and Robert R. Bayless. "Performance and Supportability - A Necessary Synergism," Air Force Journal of Logistics (Spring 1987).

33. McCathy, Vance. "Castor Drums Up Ada Fans," Federal Computer Week, Unpublished (27 July 1987).

34. Melmick, Walter, Electronics Engineer. Personal interview. AFWAL/FIGR, Wright-Patterson AFB OH, 22 July 1987.

35. Morgan, Reed, Program Manager. Personal interview. AFWAL/AAAS-1, Wright-Patterson AFB OH, 3 August 1987.

36. Morris, David, Project Engineer. Personal interview. AFWAL/FIEMA, Wright-Patterson AFB OH, 27 July 1987.

37. Mukai, Dennis, Electronics Engineer. Personal interview. AFWAL/AARM, Wright-Patterson AFB OH, 27 July 1987.

38. Northrop Aircraft Division. High Reliability Fighter Design Guide. Contract F33615-85-C-0114. Long Beach: Northrop Corporation, October 1986.

39. "OMB Committed to Press DOD Procurement Reform," Electronic News, 31: C (25 February 1985).

40. Packard, David. "A Formula for Action," President's Blue Ribbon Commission on Defense Management, April 1986.

41. Phillips, Larry, Aeronautical Engineer. Personal interview. Wright-Patterson AFB OH, 29 July 1987.

42. Prescott, 2Lt Catherine, Aeronautical Engineer. Personal interview. AFWAL/FIBAA, Wright-Patterson AFB OH, 11 August 1987.

43. Quaglieri, Robert, Program Manager. Personal interview. Wright-Patterson AFB OH, 20 July 1987.

44. Russ, Lt Gen Robert D. "A Formula for Action," President's Blue Ribbon Commission on Defense Management, April 1986.

45. Schankman, Mark S. "A Proven Approach to Making the Right Logistics Decisions," Defense Management Journal, 22: 33-40 (Second Quarter 1986).

46. Silverman, Michael, Manager of Integrated Logistics Technologies Office. Personal interview. AFWAL/FIX, Wright-Patterson AFB OH, 8 April 1987.

47. Spealman, Ralph, Branch Chief. Personal interview. AFWAL/FIEA, Wright-Patterson AFB OH, 6 August 1987.

48. Stimson, Richard A. and Lt Col Frank Doherty. "Acquisition Streamlining," Program Manager, 13: 15-18 (January-February 1985).

49. ------. "Contractual Implications of Acquisition Streamlining," Contract Management, 20: 22-6 (Winter 1984).

50. Strawser, Rick, Electronics Engineer. Personal interview. AFWAL/CDLA, Wright-Patterson AFB OH, 4 August 1987.

51. Tannas, Lawrence E. Jr. Flat-Panel Displays and CRTs. New York: Van Nostrand Reinhold Co., 1985.

52. Trinkaus, John and Malcolm Corrin. "Competitive Advocacy and Spare Parts," Journal of Purchasing and Materials Management, 20: 22-5 (Winter 1984).

53. VHSIC Annual Report for 1986, VHSIC Program Office, Office of the Under Secretary of Defense for Acquisition, 31 December 1986.

54. Von Spangenberg, Marconi. "USAF's 'Fighter Mafia' Needs a New Article Design Philosophy," Armed Forces Journal, 123: 64-68 (March 1986).

55. Wade, James R. Jr. "Defense Logistics: The Case for Reform," Defense Management Journal, 22: 3-6 (Fourth Quarter 1986).

56. Weimer, Joseph, Project Engineer. Personal interview. AFWAL/POOC, Wright-Patterson AFB OH, 17 July 1987.

57. Weimer, Joseph and Ishaque S. Mehdi. "Fault-Tolerant Electrical Power System," unpublished paper.

58. Werner, Robert, Deputy Branch Chief. Personal interview. AFWAL/AADA, Wright-Patterson AFB OH, 4 August 1987.

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## Abstract

The importance of high reliability systems in the national defense strategy of "force multiplier" is paramount. Currently, the Air Force has adopted Reliability and Maintainability (R&M) 2000 as a management policy to achieve high reliabilities. However, there are few methods being implemented which can improve the measures of reliability. One method used with success by satellite systems is the use of expensive, but highly reliable class S electronic parts as opposed to the class B parts used in avionics and ground electronic systems. A methodology for determining the improvement of systems' Mean Time Between Failure (MTBF) was developed. Additionally, the impact of improved system MTBF along with higher acquisition costs as a result of using class S parts was analyzed in a life cycle cost model. The results obtained in this research indicate that class S parts have the potential to significantly increase MTBF while actually lowering life cycle costs. Recommendations for follow-on research are given.

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